LEFT HAND CREEK
FISH PASSAGE REPORT

May 2021

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Prepared by

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This report explores solutions for restoring and reconnecting fish habitat while meeting the goals, needs, and legal rights of diversion owners. As described further in this report, the Left Hand Creek community values and celebrates our ditches and diversions, which have supported our society and landscape for generations. Accordingly, habitat restoration and reconnection are examined through the lens of potential to benefit and support diversion owners while reconnecting the greatest length of stream miles for fish passage. Close partnership and communication with diversion owners and managers, as well as fish biologists, were critical to this report.

In Section 1, we examine the unique context of Left Hand Creek as a "working river," focusing on the economic and ecological benefits provided by the river. In Section 2, we discuss fish populations, presenting results from our assessment of past and present fish community characteristics (types of species) and their distribution (where they exist in the creek) throughout Left Hand Creek. As part of this discussion, we consider possibilities for future fish populations in Left Hand Creek based on what communities have existed historically. In Section 3, we investigate limitations (physical barriers) to current fish populations in Left Hand Creek. In Section 4, we discuss possible solutions, considering what we know about past and present watershed conditions, and what needs and challenges are expected in the future.

Left Hand Creek as a Working River

Like many of Colorado's Front Range rivers, Left Hand Creek is considered a working river because it provides considerable economic and ecological benefits for our communities. Left Hand Creek is celebrated for the ditches and diversions that supply water for irrigated agriculture and drinking water, as well as aquatic habitat that sustains fish populations. Together, these economic and ecological services enhance our community's quality of life. As beneficiaries of these services, it is our responsibility to explore ways to balance ecological health with economic needs now and in the future. To start this process, this section introduces the context of Left Hand Creek as a working river.

Left Hand Creek exists within the larger St. Vrain Basin of the even larger South Platte Basin (Figure 1). In addition to Left Hand Creek, the St. Vrain Basin includes St. Vrain Creek, Boulder Creek, Coal Creek and their tributaries (Figure 2). It extends from its headwaters just east of the continental divide at Left Hand Park Reservoir down steep canyons and through the high plains and the City of Longmont, where it then joins the St. Vrain Creek. It is a cold headwater tributary that is primarily fed by annual snowmelt. Much of the creek's existing hydrology, morphology, and ecology reflect centuries of management and land use change throughout the watershed. Typically, Left Hand Creek's hydrograph is characterized by flushing flows from May through July (driven by snowmelt) and low flows through the remainder of the year (driven by groundwater recharge and intermittent rainstorms) (Watershed Center 2020). Yet the main influence on our hydrograph is the demand for domestic and agricultural water diversions.

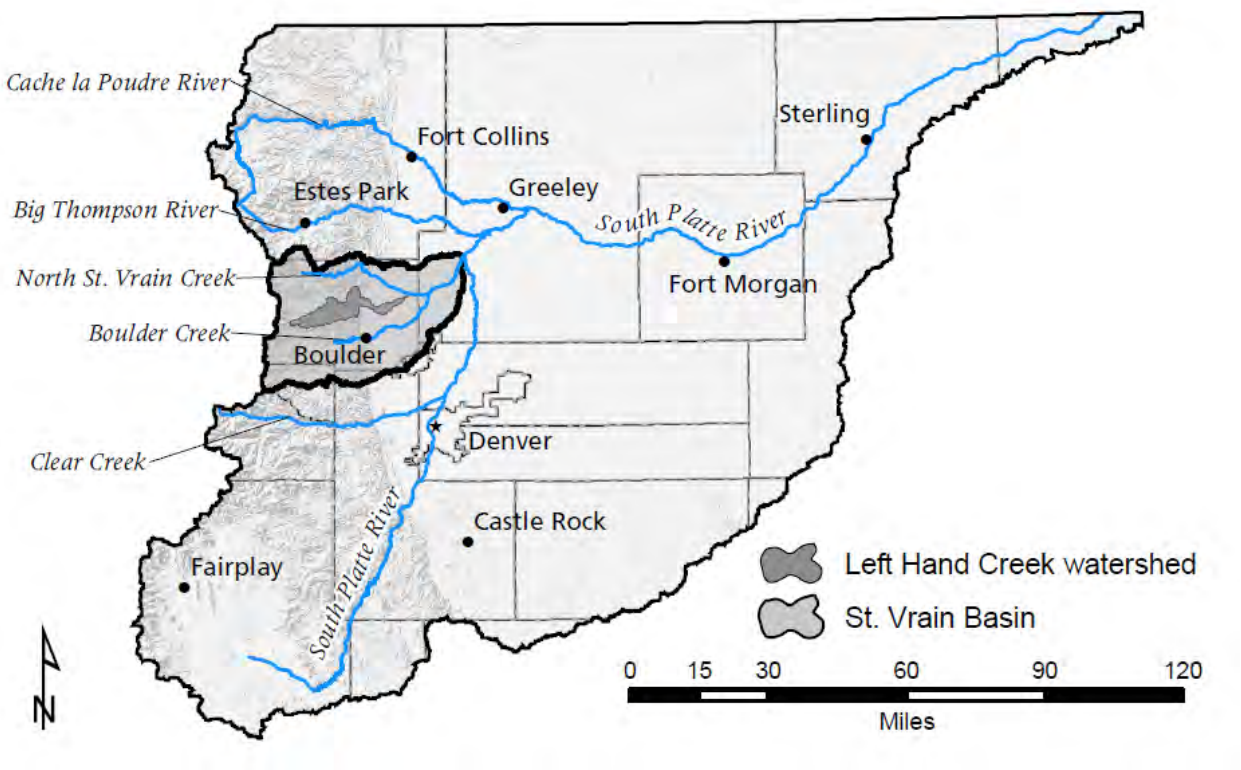

Figure 1. A map of the South Platte Basin in Northeast Colorado. The St. Vrain Basin and Left Hand Creek Watershed are shaded. Figure prepared by Colorado Parks and Wildlife.

Domestic and agricultural diversions are the lifeblood of our land, celebrated for bringing water, habitat, and life to places that would otherwise be dry. Similarly, land and water owners that own and manage ditches and diversions are watershed stewards, leading our communities through a way of life that has sustained generations for over 100 years. Throughout Colorado, water is diverted from rivers and creeks into ditches that carry water to end users. On Left Hand Creek, the Left Hand Ditch Company uses the creek to deliver water for both agricultural and domestic purposes. Once water is diverted off Left Hand Creek, additional ditches owned by other individual ditch companies/users carry the water for farms, water treatment plants, and other uses. Water diverted for agriculture that is not absorbed (by plants, soils, etc.) or evaporated, then returns to the creek as a return flow. Return flows have many entry points and increase in-stream flows at each of these entry points.

The history of the Left Hand Ditch Company dates back to the 1800s when farmers settled in the lower watershed. These farmers began diverting water from Left Hand Creek to grow crops in the semi-arid environment. At this time Left Hand Creek was a seasonal creek that dried out in late summer. Then, in 1860, farmers constructed one of the first trans-basin diversions in Colorado, the South St. Vrain Diversion. Conveyed through a constructed dam, gates, and ditch, the South St. Vrain Diversion takes water from the neighboring South St. Vrain Creek (headwaters at Lake Isabelle) into Left Hand Creek via James Creek, a tributary located just west of the town of Jamestown. This historic trans-basin diversion is notable for its influence on western water law and for increasing the amount of water that the creek

carried compared to its natural state. Combined with return flows, this increase contributed to the creek's transformation into a working river that provides significant economic and ecological benefits for communities.

Today, the Left Hand Ditch Company system includes the Left Hand Park Reservoir and the South St. Vrain Diversion in the upper watershed, as well as an extensive ditch and reservoir system throughout the watershed. The Left Hand Ditch Company is owned by shareholders that call for water for their use. The Left Hand Ditch Company responds to shareholders' water demand when deciding how much water to release from Left Hand Park Reservoir and to divert from South St. Vrain Creek. Having just one major ditch company within a watershed is fairly unique in Colorado. In comparison, there are more than 100 individually owned ditches on St. Vrain Creek.

As described above, ditches and diversions are integral to the flows in Left Hand Creek and the way of life for our communities. In turn, diverting water poses benefits and challenges for fish populations due to changes in flows. The South St. Vrain Diversion and return flows throughout the creek provide the notable benefit of increasing the amount of water and fish habitat in the creek. Before ditches and diversions, fish were likely either permanent residents of the headwater reaches, alpine lakes, tributaries, or wetlands, or fish were seasonal visitors from other neighboring creeks during peak spring runoff. These species would then typically migrate back downstream to larger perennial creeks such as the St. Vrain or even the South Platte River. With ditches and diversions, full time flows in the creek brought in full time resident fish that rely on various habitats throughout the creek itself, ultimately benefitting the ecology of Left Hand Creek.

Yet diversions and other structures (e.g. road crossing, grade control, etc.) also limit flow in certain reaches and impede fish passage. Seasonal dry periods during irrigation season and physical barriers pose challenges for fish populations. While flows are generally maintained for perennial water delivery, there are certain times of year when sections of creek go dry or have lower than natural flows depending on water demands (SVLHWCD Stream Management Plan). Fish populations throughout the creek are also impacted by structures and diversions that limit flow in certain reaches and impede fish passage. Looking to the future, fish populations and ditch companies alike will face reduced water supply due to climate change impacts. Ditch companies may face changes in timing, duration, and magnitude of peak flows; changes in call regime; changes in timing and length of irrigation season; and/or decree limitations in relation to changing hydrology. Meanwhile fish will face drier and warmer conditions that threaten flows and water temperature. With the goal of identifying solutions for fish and barriers in Left Hand Creek, the next sections of this report discuss what we know about fish populations and barriers in Left Hand Creek, and what we can do to sustain economic and ecological benefits provided by our working river now and in the future.

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Fish Populations in Left Hand Creek

Fish are important to aquatic systems. They indicate a healthy environment, facilitate nutrient cycling that provides clean water, and provide ecosystem services for human recreation and the economy. Many of the fish populations that exist in Left Hand Creek are also found in other northern Front Range creeks in the greater South Platte Basin because of habitat connectivity (Figure 1). Foundational to habitat connectivity is that our creeks are all connected downstream and are part of a vast network of small headwater streams and larger rivers that all eventually drain to the Mississippi River. This connectivity means that, over time, a fish population in one creek could migrate to another creek through the network of streams and rivers and establish a new population. In fact, this kind of migration via habitat connectivity is essential for populations to survive negative impacts to creeks such as pollution, droughts, floods, or fire.

In addition to habitat connectivity, Colorado's Front Range streams have similar geomorphology. There are mountainous and plains sections, with an intermediate transitional foothills section, called the transition zone. These sections are geomorphologically and thermally different and provide different habitat types for fish. Naturally, fish species are distributed by the differences in habitat types. Because of this, there are three groups of fish in headwater systems: coldwater species that live in mountain sections, coolwater species that are geographically restricted to the transition zone, and warmwater species that live in plains sections (Ellis 1914; Fausch and Bestgen 1997; Haworth et al. 2020). While the larger St. Vrain Basin spans all three Front Range watershed zones and types of species, Left Hand Creek only covers a subset of the Basin, and it spans only the mountainous and transition zones with species occupying the zones throughout the year or seasonally (Figure 2). This section expands upon the fish habitat and species in Left Hand Creek by discussing the (1) mountainous and transition zone habitat types, requirements for fish and the characteristics of fish species and populations that are naturally distributed across each habitat type; (2) how these fish move throughout their lifecycle; and (3) results from a biological assessment of historical and current fish populations in Left Hand Creek. This assessment provides context for future restoration planning in the face of climate and increased water use.

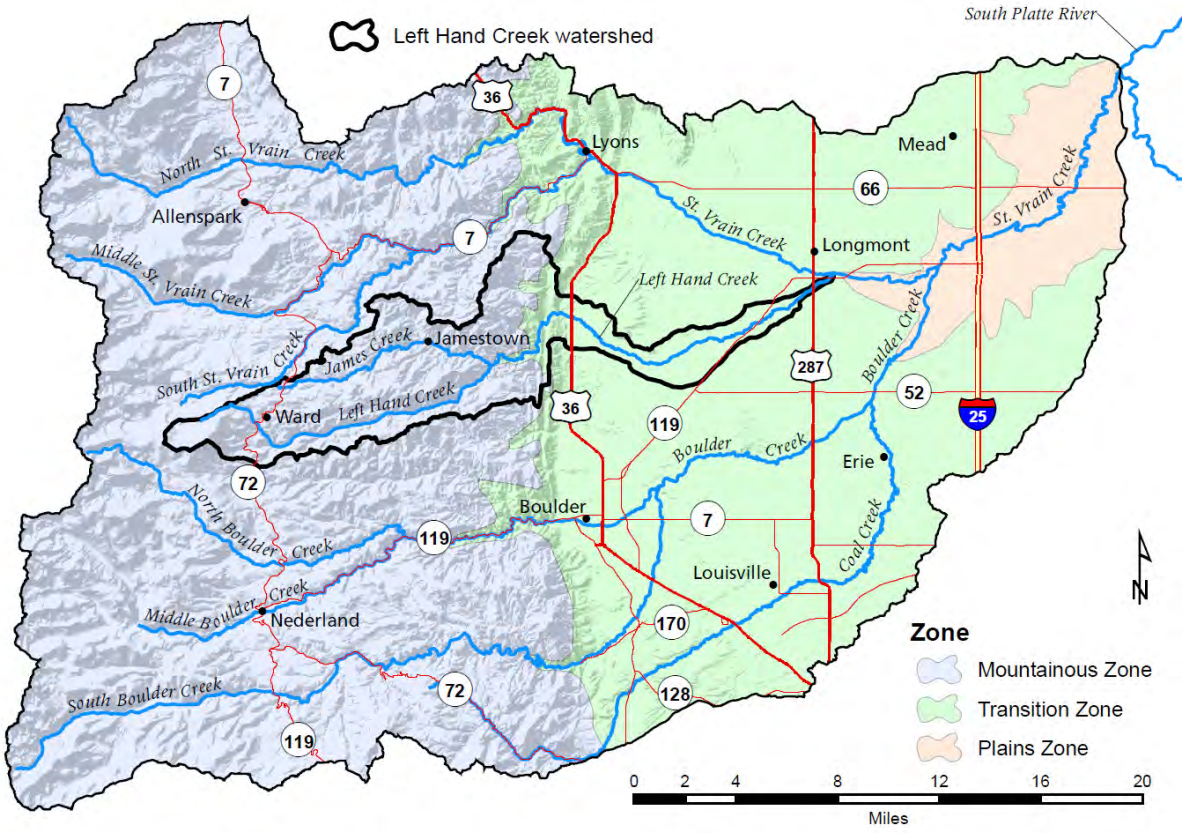

Figure 2. A map of the St. Vrain Basin with Left Hand Creek watershed outlined in bold. Geomorphic and thermal mountainous, transition, and plains zones shown by color. Here, you can see that Left Hand Creek only spans the mountainous and transition zones. The plains zone begins downstream of the location were Left Hand meets St. Vrain Creek. Figure prepared by Colorado Parks and Wildlife.

Habitat and Distribution

Natural fish distribution (the geographic area over which a species occurs) in Front Range streams like Left Hand Creek is driven by location in the watershed and resulting stream characteristics. Water temperature has been said to be an "ecological master factor" for fish (Brett 1971) and broadly explains the distribution of species along the Front Range, with marked changes in temperature, habitat, and fish community composition as streams transition from the mountains to the plains). Depending on the habitat and the creek temperature, fish populations in both zones are made up of one type or a combination of coldwater, coolwater, or warmwater species. As described above, Left Hand Creek only exists in mountainous and transition zones (Figure 3). We describe the habitat for both zones, as well as the habitat requirements of typical fish species that would be naturally distributed among the two zones, based on regional data collection and related literature. We also consider how habitat and distribution may change in the future. In some cases, limited information is available about changes in historical fish populations due to limited historical data collection and lack of records about various stocking activities.

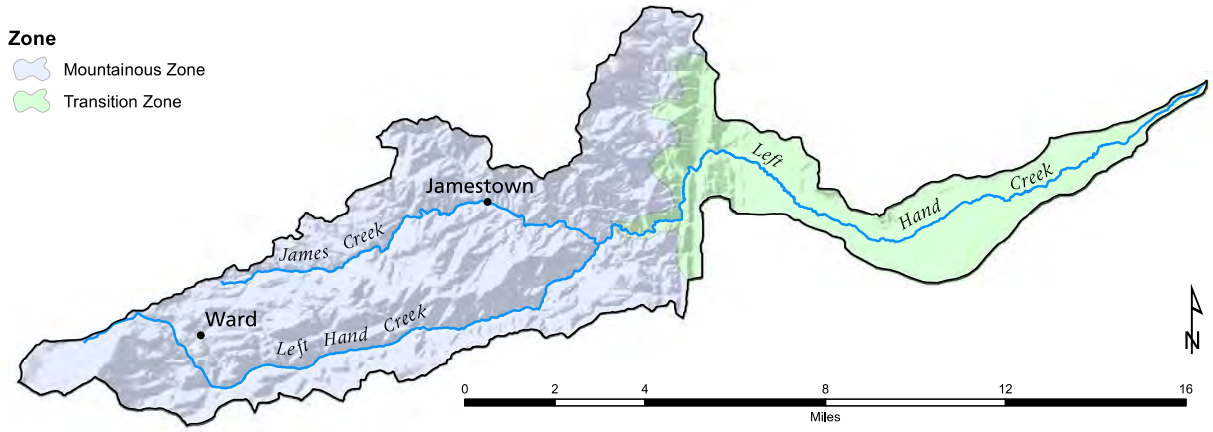

Figure 3. A map of Left Hand Creek watershed showing the mountainous and transitional reaches. Figure prepared by Colorado Parks and Wildlife.

- **Mountainous**
    - **Habitat Descriptions and Requirements of Typical Fish Populations**: In the mountainous canyon region, streams are steep, cold, and fast flowing. Mountain streams have rocky substrate and their floodplain is confined and often forested, though they also feature interspersed alluvial valleys. Water flowing in these reaches is well oxygenated and low in dissolved nutrients. Critical habitat for fish in these reaches includes pools, clean riffles, and side or backwater channels. Pools formed by large woody debris or boulders (plunge pools) are used for refuge and overwinter habitat. Clean and well oxygenated riffles are essential forage (feeding) and spawning grounds. Side channels and backwater are important to juvenile fish for forage and refuge.
    - **Fish Species and Population Characteristics**: Within these reaches, fish are hardy and strong swimmers. Typically, mountain streams are called “trout streams.” Trout are larger-bodied and strong swimmers with high jumping ability. They are also visual predators that feed on invertebrates found in clean rocky substrate and drifting in the water column. Invertebrates are a primary food source, as dissolved nutrients are limited. Today, the mountainous reaches of Left Hand Creek are home to three introduced or non-native species of trout: Brook Trout, Rainbow Trout, and Brown Trout. Historically, these reaches would have likely been home to the native Greenback Cutthroat Trout (Colorado’s State Fish!). Populations of Greenback Cutthroat Trout were nearly driven extinct by early mining and timber operations and over-fishing, followed by competition and predation by stocked non-native trout. Greenback Cutthroat Trout are not currently present in Left Hand Creek.
- **Transition**
    - **Habitat Descriptions and Requirements of Typical Fish Populations**: Between the two distinct mountainous and plains watershed zones in the Front Range is the transition zone. The transition zone extends from the mountainous foothills through the high

plains. These streams are dynamic, as they shift from cold to warm and steep and fast flowing to less steep and slow flowing systems. Instream, the transition has a mix of both mountainous and plains habitat for local species. Floodplains are widening and substrates are a mix of cobbles, gravels, and sands. Water quality is well oxygenated, especially during peak flows. It also may be impacted by surrounding land use (e.g. residential, urban or agricultural). Habitat in these reaches include pools, riffles, seasonally accessible floodplains during high flow, and side and backwater channels. This habitat is also seasonally critical for multiple life stages of fish: in the spring, this habitat is used as spawning grounds, feeding grounds, nursery grounds, and refuge. In the winter, some mountain species find refuge in deeper pools

- **Fish Species and Population Characteristics**: Transition species can tolerate the dynamic and flashy nature of transition zone streams. The range in habitat features in the transition zone result in a higher number of species, due to the combined presence of warmwater plains species (e.g catfish, sunfish, some minnows, and darters), coldwater species (e.g. trout), and coolwater species specialized to these reaches (e.g. sucker, other darters, and minnows) (Haworth et al. 2020). Note that minnow refers to a specific family of fish, including carp, dace, true minnows, and shiners, not a term for baby fish. This zone is also home to highly specialized coolwater species such as Common Shiner, Northern Redbelly Dace, and Plains Topminnow that rely on this specific habitat. Conserving these species is increasingly important because their populations are being negatively impacted by increased human influences in the transition zone (Fausch and Bestgen 1997; Haworth et al. 2020). For example, populations of native fish in the transition zone have been impacted by habitat loss, including stream channelization, dewatering, fragmentation, altered hydrology, and pollution. Similar to the mountains, they are also threatened by the introduction of non-native species (e.g. Brown Trout and Largemouth Bass).

Movement and Life Cycle

While fish populations require adequate year-round habitat within their respective watershed zone, they also require access to other habitats that may require movement from one section of creek to another. Throughout their lifecycle, flow and temperature drive movement. Seasonal high flows allow for passage, and changing flow and temperature cue fish to move. In Left Hand Creek, and many other Front Range creeks, flow and temperature are impacted by human influences including water management activities. Flows are highly regulated and sometimes nonexistent (e.g. no flow or dry conditions downstream of diversions) depending on water demands. Consequently, increased water temperatures and decreased dissolved oxygen resulting from low flow/dry conditions could be life threatening (e.g. too warm). While the fish that exist in Left Hand Creek today are the survivors of these impacts over the years, their ability to move between habitats and along stream miles is critical to sustaining populations now and in the future.

Like all living things, fish need adequate habitat for their own survival and the survival of their young, but movement between habitats is particularly essential for survival. Throughout their life cycle, fish

may move miles throughout the watershed zones to find adequate habitat. For many fish species, their life cycle includes four main stages: egg, fry, juvenile, and adult. Each stage of the life cycle is characterized by distinct survival needs and preferred habitat. The four main stages, required habitat, and fish movement required to access these habitats are described below.

- The egg dispersal stage requires well oxygenated water and eggs need to either attach to vegetation and substrate, float freely in open water, or be deposited in the gravel bed of riffles. As spring runoff recedes, saturated wetlands or ephemeral (seasonally flowing) tributaries and side channels provide adequate spawning or egg dispersal habitat. For mountainous and transitional species, access to this habitat may require movement upstream or downstream to wetland complexes, flowing side channels, and tributaries.
- The fry and juveniles stage requires protected habitat with cover, slower-moving water, and enough forage to support the growing fish. During the end of spring runoff, when flows are decreasing, fry and juveniles feed in the protected wetlands, side channels, and tributaries. As flows recede, they may move back downstream or upstream to dependable habitat where there is adequate water depths, protection, and forage throughout the low flow season (late summer through winter). For some warmwater species, backwater areas that are connected throughout the year may also be important.
- The adult stage requires protected habitat with enough water depth and forage to support fish growth and future reproduction, as well as enough flow to support movement to spawning grounds. Adult fish use both seasonal spring runoff and low flow habitats. As described for the egg stage above, adults will migrate upstream or downstream to spawning grounds and migrate back to low flow holding water each year over the course of multiple years. Certain native species may spend their entire life in single off-channel pond along the floodplain, but rely on high flows that inundate these ponds and allow young to disperse to other similar habitats.

Habitat, Distribution, and Movement in the Future

Climate change and human influences will impact fish habitat, distribution, and movement in the future. It is well established that future climate conditions are expected to be drier, warmer, and flashier. Meanwhile human influences through population growth are expected to increase throughout Front Range communities. Given these predictions, increased water use and drought will pose challenges for fish populations and water management alike.

Drought and a warmer climate pose threats to flow and water temperature. Reduced springtime high flows result in less critical seasonal habitat required for reproduction, as well as less year-round water availability required for reliable habitat through hot summers and the winter. Moreover, fish are cold blooded and warmer conditions will disrupt distribution and movement because temperature is the “ecological master factor” for fish (Brett 1971). Regionally isolated species found in the transition zone may be particularly challenged by drier and warmer conditions because thermally suitable habitat may shift upstream to reaches that are not physically suitable for these fish (i.e. too fast flowing and substrate too large) (Rahel 2002). Therefore, future suitable habitat for these species will be limited. Flashier weather patterns and events may also stress fish populations with limited habitat availability. For example, intense fire may impact the suitability of habitat with increased sedimentation from the

surrounding watershed. Increased frequency of floods may also stress populations by naturally flushing and redistributing species.

Future human influences also threaten habitat suitability and exacerbate the impacts of climate change. Development resulting from population growth alters stream and riparian habitat by over simplifying channels and complex habitat; altering hydrology, thermal regimes, and sediment transport; and fragmenting available habitat (Haworth et al. 2020). Impaired habitat may only be further impacted by warmer, drier, and flashier conditions. In Left Hand Creek, maintaining habitat suitability while meeting water demands is of particular concern looking into the future, as the creek has a vast water delivery network throughout the mountainous and transition zones (see Section 3).

Considering the challenges fish populations will face in future climate conditions, as well as Left Hand Creek's inherent role as a working river that supplies water for irrigated agriculture and drinking water, future restoration projects should consider the following goals and objectives:

- Improving efficiency and maintenance activities of water delivery at diversion structures while improving instream habitat or seasonal fish passage (e.g. allowing for fish passage or instream flows when water is not called upon);
- Increasing connected stream habitat miles so that isolated populations have more habitat availability to accommodate future climate and human influence;
- Extending the distribution of native species upstream by improving habitat connectivity and/or stocking to areas where they were found historically, so that transition zone species can adapt to warmer and drier conditions.

Biological Assessment

The Watershed Center completed a biological assessment of fish in Left Hand Creek to understand how the distribution of fish populations differs today from historical records, what distribution may be possible in the future based on what existed historically, and what fish species should be considered when assessing fish passage barriers and finding balanced solutions for the future. Given the importance of fish distribution and movement between watershed zones, 69 years of fish community data were assessed in the mountainous and transition zones of Left Hand Creek. The assessment included a review of historic fish community data (1950 through 2019) from Colorado Parks and Wildlife (CPW) (period of record: 1950 through 2017) and supplemental field sampling (2018 and 2019) at established CPW sites. All reviewed and surveyed data were collected using a two-pass electrofishing method. Table 1 and Figure 4 below illustrate CPW's data collection history throughout this period of record and all sites that were considered during this assessment.

			Sample Year ('XX)																																
ID	**Elev. (ft)**	**CPW Location Name**	**50**	**67**	**73**	**74**	**76**	**77**	**79**	**80**	**85**	**86**	**87**	**88**	**89**	**92**	**93**	**94**	**96**	**99**	**01**	**02**	**03**	**04**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	10650	Lefthand Cr Reservoir		X	X							X		X	X		X	X	X			X			X									
2	10406	250ft US of bridge BLW res						X																											
3	8955	650 M BLW Peak 2 Peak Hwy																						X											
4	8651	400 M ABV California Gulch Rd																						X									X		
5	8545	Captain Jack Lower Site																						X									X		
6	8312	below Sawmill Rd crossing					X																												
7	7994	3 mi above Gold Hill Rd											X			X																			
8	**7933**	**BOCO pullout**																															X		
9	7866	Lefthand Canyon Dr mm 12.1									X																								
10	7706	1.5mi above Gold Hill Rd											X			X																			
11	**6331**	**below James Creek confluence**				X	X							X																					
12	6311	BLW Buckingham Park																															X		
13	6039	at Lefthand Canyon Dr mm 4									X																								
14	**5638**	**ABV Geer Canyon**							X *																										
15	5523	570 N Bkw Foothills HWY (# 9)																X																	
16	**5403**	**ABV 41st St (# 8)**							X			X						X													X				
17	5309	225 M ABV N 49th St	X							X		X																							
18	**5201**	**600 M ABV Strath St (# 7)**							X									X																	
19	5159	ABV N 63rd		X																															
20	5114	ABV Nimbus Rd							X *			X													X						X				
21	5077	ABV N73rd St (# 6)																X																	
22	5048	ABV 81st St (# 5)		X					X									X																	
23	**5023**	**125 M ABV N 87th St.**																							X						X				
24	5011	ABV Diagonal Hwy																X					X												
25	4993	At Hover St Bridge																													X	X			
26	4973	300 M ABV Pike Rd	X									X											X												
27	4971	450 M BLW Pike Rd (# 3)																X																	
28	4951	125 M ABV Main St (# 2)																X			X	X			X	X	X	X			X		X		
29	4929	<u>350 M ABV St Vrain</u>										X								X					X				X	X	X		X	X	X

Table 1. CPW's 1950 through 2017 fish community sampling locations and events by year in Left Hand Creek and Left Hand Park Reservoir. Sampling locations are listed by ID and elevation (feet) and grouped by watershed zone (blue= mountainous, green= transition). For each location row, an 'X' indicates a sampling event during the corresponding year. Six locations in **bold** have an additional sampling event in 2018 or 2019 by the Watershed Center and consultants. The asterisk (*) at two sampling event indicates data were omitted from our analysis due to a possible error in data entry. The <u>underlined</u> location is the farthest downstream "No Barrier" transition zone site that was analyzed individually compared to all other upstream "Barrier" transition sites in our biological assessment.

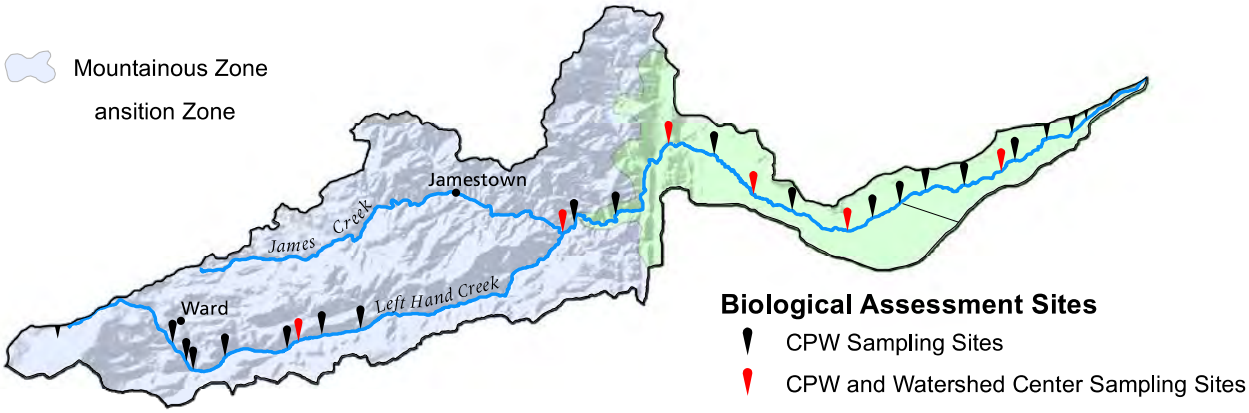

Figure 4. A map of all historical and current CPW sampling locations in Left Hand Creek and Left Hand Park reservoir since 1950. Sites with red pins were sampled again by the Left Hand Watershed Center to supplement recent data collection in 2018 or 2019 using CPW methods. Figure prepared by Colorado Parks and Wildlife. For zoomed in sampling location details, please see Appendix B.

Dataset, Analysis, and Interpretation

Our ability to analyze and interpret historical fish community data in Left Hand Creek was limited due to how much data was collected by CPW over time. Surveyed data was only available after 1950, though it is likely that many fish species disappeared from the creek prior to the earliest sampled fish records (per discussions with Colorado Parks and Wildlife). Also, while there are more than 25 sample sites in CPW's record since 1950, many of these sites were not sampled with enough frequency for assessment of impacts to communities on a finer scale (e.g. in relation to specific structures or development). For example, there were few sampling events in the upper transition zone and lower mountainous zone from the mid-1990s through early 2000s, and the most recent data collection in these areas was in 2015 (Table 1).

Considering the data limitations described above, data was grouped based on both geographic locations and time period to assess changes in communities and distribution (where species exist geographically) over time. Grouping by geographic locations helped inform our understanding of finer-scale (e.g. in relation to development and structures) changes in fish communities over time. This was particularly important in the transition zone where there is a high concentration of in-stream structures and developed reaches. Grouping by time helped inform how fish communities have changed over time despite gaps in sampling events during certain years. The Watershed Center supplemented lack of recent data collection by sampling at six existing CPW sites in 2018 and 2019 (Table 1, Figure 4).

Geographically, sites were grouped by mountainous and transition zones, and fish species presence or absence data from these zones were assessed over time. Data are shown in Figures 3 and 4. Within the transition zone, we also wanted to understand the impact of potential passage barriers on fish communities and distribution. While we could not assess all sites individually due to limited data, we were able to separate out one site that was sampled with greater frequency, especially in recent years (Table 1). This site, "350 M ABV St Vrain," is the farthest downstream site (just upstream of St. Vrain Creek) and is notable because there is no barrier between this site and the confluence with St. Vrain Creek. Due to frequency of sampling and lack of barriers at this site, it was selected as a representative

"No Barrier" site and was compared to sites with nearby barriers. "Barrier" sites were identified as sites with at least one passage barrier between the site and the confluence with St. Vrain Creek. This group included all remaining upstream transition sites, which were sampled with less frequency over time (Table 1). For example, many of these sites were only sampled once since 2007. The "Barrier" and "No Barrier" site comparison is shown in Figure 5.

Grouping by timeframe focused on two time periods: throughout history versus what has been surveyed. Timeframe was an important consideration in the biological assessment because we aimed to quantify how historical populations differ from current populations. Given that fish community data are available starting in 1950 and that the most recent major river changing event was the 2013 floods, we selected 1950 to 2019 as the historical timeframe and 2013 to 2019 as the current timeframe. Notably, the historical timeframe includes post-2013 data because it represents the overall historical record of fish populations in the creek and informs what fish populations may be possible in the future. Also, though November 2013 was selected as start of the current timeframe, we acknowledge that other stressors and human influences in the watershed have impacted fish populations since 1950 and through the early 1800s, as noted in Haworth et al. (2020). Using these two timeframes, analysis focused on quantifying presence and absence of species found within each watershed zone.

Interpretations of our analyses were also limited. First, our nuanced assessment of transition zone populations (comparison of fish populations at the farthest downstream site to all other upstream transition zone sites) only suggests possible impacts of specific structures on fish populations. More focused and intensive monitoring is required to fully interpret the impacts of specific instream structures on fish populations. Second, a limited dataset prevented assessment of the incremental impacts of human influences on fish populations over time. For example, we lacked sufficient data to determine how construction of specific diversions influenced fish populations. These human influences and their impact on fish populations are highlighted by Haworth et al. (2020) in nearby South Boulder Creek.

Haworth et al. (2020) noted multiple stressors related to human development that occurred in the Boulder Creek watershed and likely impacted native fish populations throughout time. These include beaver trapping, timber harvest, cattle grazing, mining, flow augmentation, mine spill, trans-basin diversions, reservoir construction, whirling disease, and the 2013 floods (Haworth et al. 2020). Based on proximity and our knowledge of historical development (e.g. the construction of the diversions, reservoirs and ditch system; mining in the upper watershed; and the 2013 floods), it is logical to interpolate similar activities took place on Left Hand Creek and likely that these stressors had similar impacts throughout the Left Hand Watershed. Therefore, our assessment of historical versus today's fish communities is focused on understanding the culminating loss of species over years of development that is not linked to a singular event.

Results and Discussion

For all mountainous and transition zones, we analyzed data for the presence or absence of all species we would expect to find in each zone during the two timeframes. Expected species were either (1)

surveyed and documented in our dataset since 1950 or (2) recognized as potentially able to exist in Left Hand Creek because they exist in other neighboring creeks in the St. Vrain Basin (e.g. Boulder or St. Vrain Creeks) or were reported to have existed in connected watersheds in literature (Haworth et al. 2020). The following Tables 2-3 and Figure 5 show our results, which are further discussed and summarized in Table 4.

Table 2. Fish species presence or absence data at all sampled sites in the mountainous zone of Left Hand Creek throughout sampled history and today. The table lists species that are expected in this zone, based on field surveys or literature (Fausch and Bestgen 1997; Haworth et al. 2020). For Native/Protected Status: N= Native, I= Introduced, ST= State Threatened, SC= Special Concern, SE= State Endangered, FT= Federally Threatened, EX= Extirpated (CPW 2015). For each sampling time frame, sampled species presence is indicated by an 'X' and absence is indicated by no 'X'; the number of sites sampled during each timeframe is indicated by 'n'. The collective species richness (number of species present) is listed at the bottom. These results show that mountains reaches are only occupied by non-native trout. Brown Trout in particular are an aggressive non-native predator that likely outcompete native species in these reaches, while Rainbow and Brook Trout occupy colder upstream habitat with less Brown Trout densities and competition.

Mountainous Species	**Native/ Protected Status**	**Throughout History (1950 to 2019) (n=10)**	**Today (Nov. 2013- 2019) (n=3)**
Brook Trout	I	X	X
Brown Trout	I	X	X
Greenback Cutthroat Trout	N/FT/ST		
Rainbow Trout	I	X	X
Species Richness:		**3**	**3**

Table 3. Fish species presence or absence data at all sites sampled sites in the transition zone of Left Hand Creek throughout sampled history and today. The table lists species that are expected in this zone, based on field surveys or literature (Fausch and Bestgen 1997; Haworth et al. 2020). For Native/Protected Status: N= Native, I= Introduced, ST= State Threatened, SE= State Endangered, SC= State Special Concern, FT= Federally Threatened, EX= Extirpated (CPW 2015). For each sampling time frame, sampled species presence is indicated by an 'X' and absence is indicated by no 'X'; the number of sites sampled during each timeframe is indicated by 'n'. The collective species richness (number of species present) is listed at the bottom. Collective results for the transition zone show very few species loss today compared to throughout sampled history. However, a closer look species loss within the transition zone, provided in Figure 5 below, shows that these data are skewed by high retention of species richness at the farthest downstream site. If this site is removed from the grouping (Transition_No Barrier), there is more evident species loss at sites in the transition zone where barriers are present (Transition_Barrier).

Transition Species	Native/ Protected Status	Throughout History (1950 to 2019) (n=19)	Today (Nov. 2013- 2019) (n=8)
Bigmouth Shiner	N	X	
Black Bullhead	N	X	X
Black Crappie	I	X	X
Blacknose Shiner	N/EX		
Bluegill	I	X	X
Brassy Minnow	N/ST		
Brook Stickelback	I	X	X
Brook Trout	I	X	
Brown Trout	I	X	X
Central Stoneroller	N	X	X
Common Carp	I	X	X
Common Shiner	N/ST	X	X
Creek Chub	N	X	X
Fathead Minnow	N	X	X
Gizzard Shad	N	X	X
Green Sunfish	N	X	X
Hornyhead Chub	N/EX		
Hybrid Sunfish	I	X	X
Iowa Darter	N/SC	X	X
Johnny Darter	N	X	X
Lake Chub	N/SE		
Largemouth Bass	I	X	X
Longnose Dace	N	X	X
Longnose Sucker	N	X	X
Northern Plains Killifish	N	X	
Northern Redbelly Dace	N/SE		
Orangespotted Sunfish	N		
Plains Minnow	N/SE		
Plains Topminnow	N	X	
Rainbow Trout	I	X	
Red Shiner	N	X	X
Sand Shiner	N	X	X
Stonecat	N/SC	X	X
Suckermouth Minnow	N/SE		
Western Mosquitofish	I	X	X
White Crappie	I	X	
White Sucker	N	X	X
Species Richness:		**29**	**23**

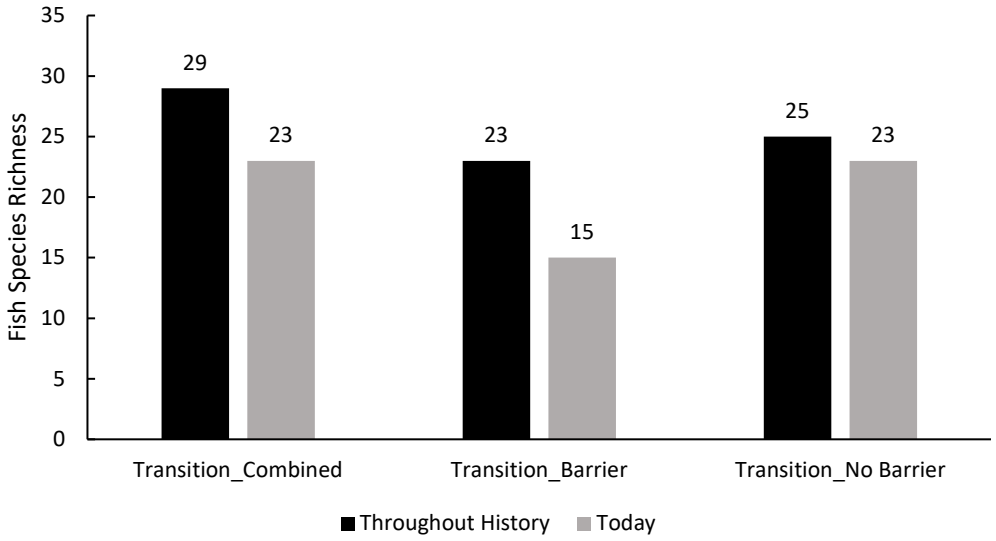

Figure 5. Fish species richness (all species present) and general distribution (where species are found in a geographic area) relative to presence or absence of barriers within the transition zone throughout sampling history (1950 to 2019) versus today (Nov 2013 to 2019). Richness is indicated for all site groupings above each bar. Combined richness for all transition sites, Transition_Combined, is shown for reference (see Table 3 for details). General distribution relative to presence or absence of barriers within the transition zone is shown as richness for sites with barriers and the farthest downstream site with no barriers. The Transition_Barrier category includes data from 18 CPW sites in the transition zone that have at least one barrier between the site and the Left Hand confluence with the St. Vrain. They are not assessed individually due to limited data. The Transition_No Barrier category represents one sample site with no barrier between the confluence. This site had enough sample year data to assess the site individually. These data show that throughout sampling history and today, many of the species sampled in the transition zone are found at the farthest downstream site (without downstream barriers), while all sites upstream of at least one barrier have fewer species. The greatest loss in species richness from throughout history vs. today also occurs within the upstream Transition_Barrier sites. This may be related to human influences and fish passage barriers in the upper reaches of the transition zone and the inability of diverse populations downstream to access these upstream habitats. See Appendix B for the names of species present during these timeframes at these site groupings.

Table 4. Key takeaways, possible explanations and implications for fish populations from the biological assessment of fish populations and distribution in the transition zone over time in Left Hand Creek.

Key Takeaway	Possible Explanation	Implications for Fish Populations
1. We do not have surveyed records of certain native species that are expected to exist in Left Hand Creek based on populations in neighboring creeks. Such as: Greenback Cutthroat Trout, Lake Chub, Blacknose Shiner, Hornyhead Chub, Northern Redbelly Dace, or Orangespotted Sunfish.	While this dataset cannot account for species present prior to 1950, these species may not exist in Left Hand Creek due to decades of human influences and habitat loss. It is likely several species disappeared prior to 1950.	Diversity in fish populations is important for the overall balance of resources and the ability for populations to survive natural disasters such as flood, fire, and drought. Reduced diversity implies that fish in Left Hand are facing challenges that are inhibiting survival. Reconnecting habitat may benefit possible introduction of these species to Left Hand Creek.
2. There is greater species richness (number of species) in the transition compared to the mountainous zone.	This is naturally caused by habitat availability, as described in Section 2. Habitat and Distribution.	This is an expected and natural trend for fish populations in headwater streams as species diversity increases with more habitat downstream. The native richness in the transition zone is of particular importance, as it is home to a number of highly specialized species of concern. Current and future stressors, such as non-native species competition, human influences, and climate change may reduce species richness in areas and threaten the survival of specialized species.
3. Non-native Brown Trout exist throughout the mountainous and transition zones.	Brown Trout are an aggressive predator species that was historically stocked in Front Range creeks for fishing, that now maintain self-sustaining populations	Increased competition and predation. Sportfish such as Brown Trout, which are a non-native imported species, are known for preying upon and outcompeting native species. Since Brown Trout are found throughout Left Hand Creek, they are likely adversely impacting success of native species.

Key Takeaway	Possible Explanation	Implications for Fish Populations
4. Throughout sampling history and today, many of the species sampled in the transition zone are found at the farthest downstream site, while all upstream sites have fewer species. The greatest loss in species richness occurs at upstream transition zone sites with barriers (Figure 5).	While we cannot identify the exact cause for this shift due to having limited data, it may be due to: • Combined impacts of human influences in the upper reaches of the transition zone resulting in physical, chemical, and biological changes. For example, floodplain development reduces riparian and wetland habitat, water management changes flow, sediment, and thermal regimes, and these impacts change the biological community. • Passage barriers (e.g. grade control and diversions). These structures occur throughout the transition zone and likely inhibit fish movement from downstream to upstream habitat. • Fragmented and overcrowded habitat. If fish are confined between barriers, they compete for fewer resources and are unable to migrate to suitable habitat. This makes them more vulnerable to predation, especially by the non-native introduced fish species. Also, when a localized event such as dry up or chemical spill occurs in a confined reach, downstream fish are not able to recolonize that area.	Distribution of fish populations in Left Hand Creek is inhibited by one or a combination of these factors. Transition zone fish populations have been adversely impacted by human influences for decades. They are also threatened by non-native competition for limited habitat space and predation. Instream barriers limit the greater number native species we find in the farthest downstream site to reach suitable habitat upstream. Without access, species richness and/or abundance may continue to decline at upstream sites or certain species may be extirpated (no longer exist) from these fragmented reaches entirely.

While our results identify multiple challenges for fish populations in Left Hand Creek, one key takeaway is a notable loss of species richness (number of species) in the transition zone, upstream of the farthest downstream sites. As stated, this zone is also particularly important for fish because it provides critical seasonal migration habitat necessary for plains species survival. Finally, several recent watershed restoration projects completed in this zone helped add and improve fish habitat. Given our goal of reconnecting fish habitat, these results highlight the importance of focusing partnerships in the plains-foothills transition zone for habitat restoration and reconnection.

Barriers in Left Hand Creek

While Front Range streams have been impacted by many forms of human influences since the 1800s, this report focuses on the impacts of physical in-creek infrastructure within Left Hand Watershed. Physical in-creek infrastructure comes in many forms including diversion structures, grade control structures, culverts, and other road crossings. Any of these structures may create passage barriers to fish based on stream flow, water depth, or vertical height of the structure. A stream flow or velocity barrier occurs when a structure makes stream velocity too high for a fish to swim upstream. A water depth barrier occurs when a structure creates a stream depth that is too shallow for a fish to swim upstream. A vertical height barrier occurs when the physical structure of a barrier is too high for a fish to jump over. (CPW Guidelines). While some passage barriers threaten fish populations by fragmenting sections of creek and limiting aquatic habitat, it is important to note that some passage barriers also benefit native fish populations by blocking predatory non-native fish from reaching native fish populations. A good example of this would be isolating a headwater drainage upstream of a barrier that blocks non-native trout from reaching native Greenback Cutthroat.

Barriers are also defined by the fish species that may be swimming over a structure, also known as the species of interest. Fish species have diverse swimming abilities that facilitate passage over barriers with certain characteristics (e.g. a barrier to a small plains fish may not be a barrier to a larger trout). Understanding the characteristics of each physical barrier as they relate to fish needs is necessary to consider potential habitat restoration and reconnection options. This section discusses how physical barriers impact fish and how barriers on Left Hand Creek were assessed to inform potential solutions.

Physical barriers fragment sections of creek, resulting in limited aquatic habitat and fragile sub populations. Habitat is also limited by the diversions themselves. For example, many bridge crossings, culverts, or diversions require channel modifications that direct stream flow to the center of the channel. This concentration of flows increases velocity and channel incision, creating a disconnection from the floodplain. Where this is the case, fish have limited feeding grounds or protection along the channel margins (floodplain). Physical barriers such as diversion structures can also “sweep the creek,” directing all surface flow out of the creek towards a ditch. This is a legal activity which typically occurs during the summer when all the water in the creek is necessary to meet domestic or agricultural needs. This results in downstream dry up conditions, though the creek eventually replenishes further downstream as irrigation groundwater or return flows recharge the creek.

Barriers also create habitat fragmentation, where creek sections are blocked off by upstream and downstream infrastructure. While barriers can be beneficial for conservation of certain species (e.g. Greenback Cutthroat Trout), it is also advantageous to reconnect habitat in downstream reaches due to

the fragility of isolated sub-populations. Sub-populations are vulnerable because they have no ability to migrate away from local or watershed wide disturbances such as dry up conditions, wastewater effluent, or heavy sedimentation. For example, during dry conditions, fish become stressed because they are forced to concentrate and share limited resources (e.g. food, protection, dissolved oxygen) in available groundwater-fed pools, or migrate downstream if possible.

Depending on the species of interest (the fish species that may be swimming over a structure), physical barriers can be either total or partial barriers. Total barriers are impassable by the species of interest throughout the year and partial barriers are impassible seasonally. Lack of seasonal passage means that fish cannot pass either during low flow when species cannot attain burst speed or jump height, or during high flow when stream velocities are concentrated through a barrier and are too high for a species' swimming abilities. Both types of barriers reduce or completely block the ability of fish species to move to necessary seasonal habitat and recolonize important habitat.

Barriers Assessment

Between 2018 and 2020, Left Hand Watershed Center staff and GEI Consultants applied what we learned from the Biological Assessment to assess barriers throughout Left Hand Creek. The Barriers Assessment consisted of evaluation of all physical barriers throughout the majority of Left Hand Creek. The Left Hand Creek survey area extended from the canyons to the confluence with the St. Vrain Creek downstream of the City of Longmont. All structures were observed during low flow conditions to reduce variability and optimize instream visibility. Permissions for assessments were obtained from the Left Hand Ditch Company and from the City of Longmont.

This assessment aimed to map and characterize all barriers by considering species of interest, water availability, and structural characteristics. Species of interest were species surveyed in each watershed zone during the Biological Assessment (Section 2). This was a critical first step in the barriers assessment because different species have different swimming abilities that enable them to pass barriers.

Swimming abilities include prolonged speed, burst speed, and jump height. Prolonged speed is correlated to the stream flow velocities that a fish species can tolerate (maintain position or swim upstream) for an extended period of time. Burst speed correlates with stream flow velocities that a fish species can tolerate (maintain position or swim upstream) for a short period of time. Jump height is the vertical height a fish species can jump over given the necessary burst speed.

Barriers in the geographic transition zone were evaluated by swimming abilities of transition zone species, while mountainous zone barriers were evaluated by swimming abilities of mountainous and seasonal migratory species. Swimming abilities are also dependent on water availability during high and low flow conditions and the vertical height of the barrier. Therefore, when evaluating a potential barrier, we considered the following five questions during high and low flow conditions:

1. What current or potential species need to be able to pass the barrier? This is the species of interest.
2. What is the stream velocity through or over the barrier? Is the barrier increasing stream velocity beyond the species of interest's prolonged and burst speeds?
3. What is the water depth over of the barrier? Is the water depth too shallow for the species interest to obtain prolonged or burst speeds to pass?

4. What is the water depth downstream of the barrier? Is the water depth too shallow for the species of interest to obtain burst speed to jump over the barrier?
5. What is the barrier height? Is the barrier vertically too high for the species of interest's burst speed and jump height?

While considering these questions, we classified each barrier by vertical drop height, structure type, and structure location. After compiling this information, we classified each structure as a total or partial barrier. Partial barriers were further defined by seasonality: partial barriers during low flow versus high flow. Though some species spawn in the fall, native spawning generally occurs in the spring. For this reason, it was important for this assessment to identify high flow partial barriers that may limit spawning or feeding success of migratory species and the overall success of native populations. Figures 6 through 8 below show examples of partial and total barriers in both zones and the map Figure 9 that follows shows all identified barriers.

Figure 6. Example barriers in the lower transition reaches for lower transition fish species of interest (e.g. dace, minnows, suckers, catfish). Photo A. Large jump height and low water depth make this a partial barrier because lower transition species lack the swimming ability to jump or swim between boulders during low flow. Photo B. Large jump height and high flow velocity make this a total barrier because lower transition species lack the swimming ability to jump or swim between boulders all year. Notably, high flow velocity is caused by a confined boulder notch (v-shaped indentation in the boulder, see arrow) that concentrates flow.

Figure 7. Example barriers in the upper transition reaches for upper transition species of interest (e.g. dace, suckers, trout, minnows). Photo A. Large jump height over the diversion weir and high flow velocity make this is partial barrier for upper transition species. The high flow velocity is caused by a sand sluice (confined notch in diversion structures that allow for sediment to pass downstream), which is covered by snow in photo, concentrating flow. While foothills and plains-foothills species lack the ability to jump the weir, some species (likely trout and possible suckers) could potentially pass the barrier by swimming across the sand sluice during low flow. Photo B. Large jump height and lack of step-pool that provides holding (resting) water within the concrete-enforced cascade leading up to the diversion weir make this a total barrier for foothills and plains-foothills species. Holding water is critical in cascades as it offers slower moving water that fish use for rest prior to jumping and continuing passage.

Figure 8. Example partial barriers in the mountainous reaches for canyons species of interest (e.g. trout). We did not identify any total barriers in these reaches. Photo A. Shallow pool depth downstream of boulders makes this a partial barrier for mountainous species during low flow because trout are prevented from building up the necessary jumping speed to cross the barrier. Photo B. Low water depth over the concrete bridge footing makes this a partial barrier for mountainous species that cannot swim across the footing during low flow.

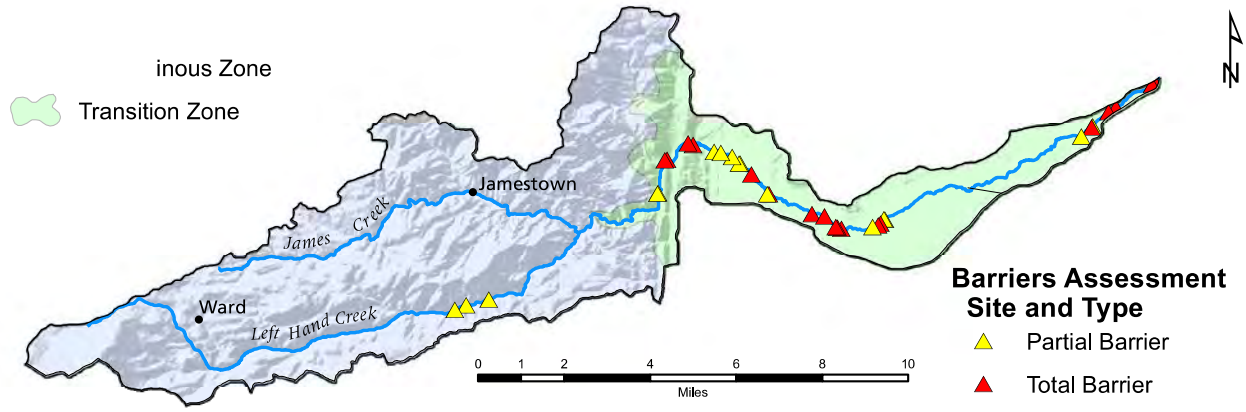

Figure 9. All 34 total and partial barriers identified in the barriers assessment on Left Hand Creek. Barriers with red pins are total barriers and yellow pins are partial barriers. Figure prepared by Colorado Parks and Wildlife. For zoomed in barrier locations, please see Appendix C.

We identified a total of 34 barriers, 19 of which were total barriers to zone-specific species of interest and 15 of which were partial barriers (Figure 9). Surveyed barriers included: 13 diversion structures, eight road crossings, 16 grade control structures, one recreational dam, one stream gage, and one beaver dam. Results are as follows:

1. Not many passage barriers in the canyons. There were five partial barriers and no total barriers; the partial barriers were road crossings with Lefthand Canyon Drive, natural cascades, or bedrock.
2. The majority (29/34) of surveyed barriers occur in the transition zone reaches.
    a. Many of these barriers existed in two clusters: from two miles upstream of US Highway 36 downstream to 63rd Street, or in the City of Longmont between Sunset Street and just downstream of Ken Pratt Boulevard.
    b. Of these structures, nearly half (13) were diversion structures owned and operated by the Left Hand Ditch Company. These structures are primarily total barriers.
3. Clusters of fish passage barriers in the transition zone overlap with areas where we no longer see historical fish species presence (see Biological Assessment).

Overall, this barriers assessment, combined with results from our biological assessment, highlights the need for fish passage and water availability in the transition zone.

Potential Solutions

Potential solutions aimed to identify priority barriers that could be modified to achieve benefits for diversions owners while also restoring and reconnecting fish habitat. Consideration of potential solutions started with outreach to diversion owners and managers. This critical step helped ensure that diversion owners and managers were supportive of the study, and remained engaged and involved throughout study. Notably, prior to starting this study, the Left Hand Watershed Center worked with diversion owners and managers on previous watershed health restoration projects and developed trust and shared understanding that was provided a critical foundation for this project. This process is further explored in a separate Passage Playbook that is under development. Leveraging these existing

relationships, Left Hand Watershed Center explored initial solutions described below in partnership with Left Hand Ditch Company, Left Hand Water District, and St. Vrain and Left Hand Water Conservancy District.

To help inform conversations about potential solutions, results from the biological and barriers assessment were integrated using a Multi-Criteria Decision Analysis (MCDA) prioritization approach. This approach is described under "Habitat Reconnection" below. As part of the solutions process, results from the assessments and MCDA approach were shared with diversion owners and managers to help inform a shared understanding about that status of fish communities and their distributions and barriers in Left Hand Creek. The results of this process, which is described in greater detail below, led to identification of two priority barriers that through potential modifications could achieve benefits for diversion owners and fish passage alike: Haldi and Left Hand Valley Diversion. Based on this feedback, Left Hand Watershed Center is working in partnership with Left Hand Ditch Company, Left Hand Water District, and St. Vrain and Left Hand Water Conservancy District to explore potential design solutions at both of these locations that achieve benefits for water owners and managers, as well as fish.

Priority Barriers for Habitat Reconnection

An MCDA tool was used to identify barriers that, if made passable, could achieve the greatest benefits for fish habitat connectivity, or connect the greatest length of stream. MCDA criteria were separated into three main categories: ecological benefits for fish passage and habitat, geomorphic benefits that would optimize fish habitat connectivity, benefits that consider future climate and human influences. Criteria within each category are assigned a weighted numerical score of relative importance based on project goals. Criteria scores range from one (lowest priority) to three (highest priority). Justification explaining the selection of criteria based on importance is provided in Table 5. Similarly, each barrier is assigned a separate score of relative importance according to how well it satisfies each criterion. Barrier scores range from one (most satisfactory) to four (least satisfactory). Barrier scores are then weighted against criteria scores using a sum of products calculation to identify a total barrier score for each of the 34 barriers. The highest scoring barriers are ones that best meet the most important criteria requirements, and ultimately the project goals.

Using an MCDA approach described above, we identified five priority barriers. A summary of the MCDA Matrix results with scores and rankings is provided in Table 6. Bonus Ditch (ID #96) was excluded from this prioritization because it was not included in diversion owner outreach at this time. While the MCDA provides an informative ranking based on technical information, project prioritization must first leverage existing partnerships and relationships. As noted above, this project started with relationship building and diversion owners and manager outreach. This critical step is foundational to a successful project and MCDA, biological assessments, and barriers assessments can be used to support discussions. This process is further described in the Passage Playbook that is under development. Additionally, potential future projects for specific barriers should consider site-specific impacts and desired future conditions. For example, while habitat connectivity may be improved through barrier modification projects, non-native fish species will likely continue to impact native fish species unless additional management is implemented.

Table 5. Multi-criteria Decision Analysis (MCDA) Criterion Table used to prioritize barriers that, if modified, would improve fish habitat connectivity. Each criterion has an associated level of priority weight (1= lowest priority; 3= highest priority) and justification.

Criterion	Weight (1=lowest; 3=highest)	Justification
Ecological Benefits		
Partial vs. Total Barrier	2	We want to distinguish between total and partial barriers because total barriers fragment year-round habitat and partial barriers allow for some seasonal passage during low or high flow. This criterion is weighted as medium priority because Left Hand Creek is heavily fragmented and improvements to either type of barrier will improve fish habitat.
Length of reconnected stream	3	We want to reconnect as much available habitat as possible while avoiding the uses of limited resources on a barrier that is in close proximity to another total barrier that is not slated for modification. This criterion is weighted as highest priority because our main goal is to reconnect and improve habitat.
Dewatered reaches in vicinity	1	While restoring flows to dewatered reaches is an ultimate vision, this criterion is weighted lower priority because reaches with moderate or mild dewatering already have existing fish populations that could benefit from improvement, especially in the face of future drought due to climate change.
Geomorphic Benefits		
Proximity to other barriers slated for modification	2	Some structures throughout the creek are already slated for modification or removal that will improve habitat connectivity. Modifications to additional structures in close proximity will increase habitat reconnection. This criterion is weighted as medium priority because the feasibility of removing structures in close proximity is dependent on other factors (ownership, cost, funds).
Stream stability benefits	2	Structures that cause instability or are already in need of repair could result in mutually beneficial projects for both fish passage and water owners. This criterion is weighted as medium priority because the results are mutually beneficial.
Size of barrier relative to other natural obstacles in reach	1	We do not intend to remove barriers that are similar in size and in proximity to natural structures, such as boulders or bedrock, that already impair fish passage. This criterion is weighted as low because many barriers in Left Hand Creek are unnatural and we have few natural barriers.
Future Conditions		
Proximity to native transition populations	2	Regionally isolated species found in the transition zone may be particularly challenged by drier and warmer conditions because thermally suitable habitat may shift upstream to reaches that are not physically suitable for these fish (i.e. too fast flowing and substrate too large). We also know that most of our transition zone fish exist at the farthest downstream site. This criterion is weighted medium because we want to prioritize access for existing native populations to upstream habitats.

Table 6. Summary of the MCDA Matrix results with scores and rankings. The one Allen's Lake Diversion labeled with an asterisk (*) indicates the structure was modified as of fall 2021.

Rank	Barrier Name and ID Number	Score
1	61 - USGS Gage in Canyon	40
2	55 - LHWD Haldi Intake	39
3	57 – LHCD Road Crossing over Geer Canyon Creek	39
5	98- Beaver Dam (US of Bonus Ditch, Longmont)	38
6	106- Pike Road Crossing (Longmont)	34
7	36 – LH Valley Reservoir Diversion (41st Project)	33
8	33 – LHWD pipeline DS of 41st St.	33
9	84 – LHCD Road Crossing (US barrier 110)	31
10*	59 – Allen's Lake Diversion (Canyon)	30
11	34 - Three-tier Grade Control (US 41st)	30
12	42 – Table Mountain Diversion (Ranch project)	30
13	103- Grade Control (Pipeline; Longmont)	30
14	16 - Grade Control (63 Ext. project)	29
15	94- Star Ditch? (US of Boulder Feeder/Haystack)	29
16	29 – Hinman Ditch	28
17	31 - Diversion US of 49th St.	28
18	108- Grade control (US S Sunset St, Longmont)	28
19	102- Grade Control (Longmont)	28
20	30 – Access Road Crossing (Haystack project)	27
21	92 - Grade Control (Natural bedrock)	27
22	93 - Road Crossing (Natural bedrock)	27
23	110 - LHCD Road Crossing (US Rowena)	26
24	37 - Grade Control (Ranch project)	25
25	38 - Grade Control (Ranch project)	25
26	87 - Grade Control (Natural cascade)	25
27	15 – Williamson Diversion	24
28	28 - Access road crossing at Boulder Feeder Ditch siphon	24
29	105- Grade Control (DS Pike Road, Longmont)	23
30	95- Crocker Ditch	21
31	43 - Grade Control at Hwy 36 Crossing (CDOT work)	19
32	19 - Grade Control (63 Ext. project)	16
33	11 - Grade Control (63rd project)	15
34	13 - Grade Control (63rd project)	13

Conclusions

In this report we explored solutions for restoring and reconnecting fish habitat while meeting the goals, needs, and legal rights of diversion owners. The following conclusions summarize keys points related to the process of identifying potential solutions and next steps.

- Dating back to 1860, ditches and diversions are integral to the flows in Left Hand Creek and a way of life for our communities that has sustained generations for over 100 years. As we consider the future, and especially the continued impacts of climate change and human influences, we will continue to celebrate our ditches and diversions for bringing water, habitat, and life to places that would otherwise be dry.
- Fish in Left Hand Creek are challenged by passage barriers the limit movement, with a notable loss of species richness (number of species) over time in the transition zone. This zone is particularly important for fish because it provides critical seasonal migration habitat necessary for transition species survival. Looking to the future, improved fish passage in this zone will help sustain vulnerable fish populations.
- While climate change (e.g. fire, drought) is expected pose challenges for diversion owners and fish alike, there are opportunities to develop mutually beneficial long-term solutions. These include improving efficiency of water delivery at diversion structures while improving instream habitat and connectivity.
- As we pursue potential projects, prioritization must start with relationships, notably building trust and shared understanding with diversion owners and managers. Technical assessments should supplement this foundation when identifying mutually beneficial projects.

Appendix

- Appendix A. Biological Assessment Panel Map
- Appendix B. Species Richness Tables for Transition Barrier and No Barrier Site Categories
- Appendix C. Barriers Assessment Panel Map

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